Appendix E
Preliminary Results of Loxahatchee Estuary Salinity Model

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1. Introduction

The upstream migration of salt water into the historic freshwater reaches of the Loxahatchee River has altered the floodplain cypress forest community along the Northwest Fork and some of its tributaries. A hydrodynamic/salinity model was developed to study the influence of freshwater input on the salinity conditions in the river and downstream estuary. The purpose of this modeling effort was to predict salinity conditions at various points in the estuary with respect of freshwater inflow rates and tidal fluctuations.

The model was calibrated and verified against field data that were collected from January to June of 1999. Then the model was applied to scenarios that were proposed by the study team. Two series of model simulations were requested. The first simulation (Simulation #1) included flows from the Northwest Fork of the River and its three tributaries based on flow ratios established by a previous study. The second model run was named Simulation #2 and contained a minimum amount of freshwater input from the three tributaries. Simulation #1 was used to predict salinity conditions with various freshwater inflow rates that follow historic freshwater input patterns. The purpose of Simulation #2 was to predict salinity condition on a "worst case" scenario with the Northwest Fork of the river providing the majority of water with minimum freshwater input provided by the three tributaries to the estuary.

These model results were used to provide an estimate of the volume of water needed from the Northwest Fork of the river to maintain salinity within the range that was recommended by District staff biologists.

This document outlines the basic model setup, assumptions and calibration/verification process. A summary of preliminary results of model applications for Simulation #1 is presented.

2. Model Description

2.1. Computer Model (Software) Description

The software used in the development of Loxahatchee River Hydrodynamics/Salinity Model were computer programs RMA-2 and RMA-4 that were developed by Army Corps of Engineers (USACE, 1996).

RMA2 is a two dimensional depth averaged finite element hydrodynamic numerical model. It computes water surface elevations and horizontal velocity components for subcritical, free-surface flow in two dimensional flow fields. RMA2 computes a finite element solution of the Reynolds form of the Navier-Stokes equations for turbulent flows. Friction is calculated with the Manning’s or Chezy equation, and eddy viscosity coefficients are used to define turbulence characteristics. Both steady and unsteady state (dynamic) problems can be analyzed.

The program has been applied to calculate water levels and flow distribution around islands; flow at bridges having one or more relief openings, in contracting and expanding reaches, into and out of off-channel hydropower plants, at river junctions, and into and out of pumping plant channels; circulation and transport in water bodies with wetlands; and general water levels and flow patterns in rivers, reservoirs, and estuaries.

The water quality model, RMA4, is designed to simulate the depth-average advection-diffusion process in an aquatic environment. The model is used for investigating the physical processes of migration and mixing of a soluble substance in reservoirs, rivers, bays, estuaries and coastal zones. The model is useful for evaluation of the basic processes or for defining the effectiveness of remedial measures. For complex geometries, the model utilizes the depth-averaged hydrodynamics from RMA2.

The formulation of RMA4 is limited to one-dimensional (cross-sectionally averaged) and two-dimensional (depth-averaged) situations in which the concentration is fairly well mixed in the vertical direction. It will not provide accurate concentrations for stratified situations in which the constituent concentration influences the density of the fluid. The preliminary results indicated that the model was able to predict the salinity fluctuation driven by the tide cycle and the influence of freshwater input on the salinity regime in the river. On the other hand, since the model only simulates the water movement in the horizontal direction all the output is depth-averaged. The model does not simulate the stratification that exists in the system. While the whole system is driven by the horizontal salinity gradient between the ocean and freshwater, there could be some density-induced circulation locally that could not be simulated. The SFWMD is in the process of acquiring the next generation RMA programs that can simulate currents and transport in 3-D environment.

2.2. Data Sources and Assumptions

RMA-2 and RMA-4 are two-dimensional models that are based on the real topography of the modeling area. In addition to the geographic data, the model also requires flow and tide data to form the boundary conditions. The model requires freshwater inflow data at all tributaries and tide data on the ocean boundary. Wind, precipitation and evaporation have not been included in the study at this stage.

2.2.1 Bathymetric data

Bathymetry for the model development was provided by the Florida Department of Transportation. The original survey report has not been located. Since the data was produced by a recent 1999 survey, it was assumed that the datum of the survey data was NAD 83 and NAVD 88. While the bathymetric data fit well with other data in NAD 83 and NAVD 88, the data datum is still to be confirmed by the original report or a report that describes the survey data.

The bathymetric data does not cover the upstream portion of Northwest Fork above river mile 4. The approximate channel depth was based on a bathymetric map produced by USGS in 1982 (McPherson, Sabanskas, & Long, 1982).

2.2.2 Model Datum

The model was developed in North America Datum 83 (NAD83) and North America Vertical Datum 88 (NAVD88). All the XY coordinates are in State Plane Florida East.

2.2.3 Surface Freshwater Inflows

Surface water inflow records were needed for model calibration and verification period January through June 1999. Flow records for that period at S-46, Lainhart Dam and Kitching Creek were retrieved from the South Florida Water Management District database DBHYDRO. Flow data of Cypress Creek, Hobe Grove, and North Fork for the same period was not found. A previous study (Russell and McPherson, 1983) conducted by USGS analyzed two years of the flow record and calculated the relative magnitude of freshwater inflow from each tributaries of the Loxahatchee river. The flow ratios between tributaries provided in the USGS report were applied to the calibration/verification period to estimate the freshwater flow from Cypress Creek and Hobe Grove. The upstream model boundary is the Florida Turnpike. Freshwater inflow at this location was estimated based on the flow record at the Lainhart Dam and an incremental ratio derived from the USGS data set.

2.2.4 Groundwater Inflows

One of the major tasks of model calibration was to estimate the magnitude of groundwater input to the system. Based on flow and salinity record of a dry period in May 1999, it was estimated that there was approximately 40 cfs groundwater input to the upstream portion of Northwest Fork above Kitching Creek. Groundwater seepage into the river depends on the groundwater table and the stage of the river. Before a formula is established for groundwater calculation, a constant 40 cfs was applied to model verification and subsequent scenario simulations.

2.2.5 Tide Data

Tide is a major driving force of the system. Since no measured tidal data is available, an ocean tide model developed by Army Corps of Engineers (Scheffner, 1994; Borgman and Scheffner, 1991) was applied to generate the time sequence of tide height for all the simulations. The time sequence of tide heights at 30 minutes intervals were generated by the model for an off shore location near Jupiter Inlet at Latitude North 26.94998, and Longitude West 80.04684. The tide heights were generated based on 8 tidal constituents, K1, O1, P1, Q1, N2, M2, S2 and K2.

In the model calibration process, the model output was compared with the NOAA tide data. The NOAA tide table has predicted tides for 10 locations in Loxahatchee River and its tributaries. The latitude and longitude in NOAA Tide Table (NOS, 1998) were converted to State Plane Florida East with conversion software *CORPSCON 5.11.08* developed by U.S. Army Topographic Engineering Center.

The ocean model, NOAA Tide Table and the bathymetric data use different vertical datum. The ocean model output generates tide heights relative to mean tide level. The NOAA tide table provides tide height in mean lower low water. The model output is in NAVD88. To compare with model output, tide data have to be converted to the same geodetic datum NAVD88. A research of NOAA tidal benchmark record located two benchmarks that are related to NATIONAL GEODETIC VERTICAL DATUM-1929 (NGVD29). At NOAA tide site North Fork Entrance, 0 NGVD is at 0.59 FEET MLLW. At South Jetty of Jupiter Inlet, 0 NGVD is at 1.2 FEET MLLW. In the model calibration process, the model output and NOAA data were compared at absolute elevation at these two sites. For other stations, the comparison was only on tide amplitude.

In the process of model calibration, the tide data generated by the ocean model was adjusted to reflect the amplitude attenuation over the shelf and the difference between the vertical datum NGVD29 and MTL. With a conversion formula of:

Model Boundary Tide = OceanTide*0.7+0.88',

the model output at South Jetty of Jupiter Inlet would match the NOAA predicted tide. This conversion of ocean tide was applied to all the simulations in the subsequent model simulations and produced results that are consistent with NOAA predicted tides.

2.2.6 Salinity Data

Salinity data was provided by the Loxahatchee River District for the period of record January 1994 - July 2000. Sampling equipment consisted of three Hydrolab Datasonde Model #3 monitoring probes and a data logger unit. This equipment provided readings for salinity (specific conductivity) dissolved oxygen, depth and other parameters. Data were recorded at one half hour intervals.

2.3 Model Calibration and Verification

4736 topographic data points are derived from survey data of Loxahatchee estuary to form the model grid/mesh. The XY coordinates and elevation of the 4736 points form the geometry of the model. **Figure E-1** is the finite element model mesh that was developed for Loxahatchee Estuary salinity study.

Accurate salinity prediction is based on the accurate prediction of tides. Hydrodynamic calibration and verification in tide simulations lays the groundwork for salinity simulations. The hydrodynamic model was calibrated against NOAA data for a three-month period from December 1996 to February 1997. Then the tidal output was verified against NOAA data for a four-month period from January 1999 to April 1999. Tide verification results are presented in subsequent sections.

Salinity model calibration was based on flow and salinity records from January 1 to April 30, 1999. The period includes a typical transition from wet season to dry season. While the flow record at Lainhart Dam shows a decreasing freshwater inflow to the estuary, the salinity records indicate that the salinity went up significantly even at the upstream portion of the estuary. **Figures E-2** and **E-3** are comparisons between model output and the field records at Station 64 (River Mile 7.7) and Station 65 (River Mile 8.6).

Model verification was based on the field records of the subsequent two months - May and June 1999. Starting in May, the freshwater inflow increased and salinity level dropped accordingly. Model output was depicted with two different colors in **Figure E-3**. The first portion was the model calibration result. The second portion was the model verification result. The verification result was also compared with field data at Station 66 Hobe Grove (River Mile 9.4) as presented in **Figure E-4.**

3. Model Application Results

3.1 Tides

The hydrodynamic model was calibrated against NOAA data for a three-month period from December 1996 to February 1997. Then the tidal output was verified against NOAA data for a four-month period from January 1999 to April 1999. This section describes the basic characteristics of tides in the Loxahatchee Estuary.

3.1.1 Semidiurnal Tidal Cycle

Both field data and the model simulation indicate strong tidal influence to the system. Semidiurnal tidal cycle has two highs and two lows each day with about 6 hours between each high and the next low. The semidiurnal tides generate flooding and ebbing in the estuary and cause salinity fluctuations. This tidal influence can be detected even at the far upstream portion of the Northwest Fork of the River. **Figure E-5** is the salinity record at Station 65 located at River Miles 8.6 of the Northwest Fork for March 31, 1999. Salinity was recorded as below 1 ppt at low tide at 4 am and increases to over 7 ppt at high tide at 10 am. Another pair of low and high occurred at 16:00 and 22:00.

3.1.2 Monthly Tidal Cycle

Monthly tidal cycle includes two spring tides and two neap tides. Spring tides of increased range between high water and low water occur semimonthly as the results of the Moon being new or full. Neap tides of decreased range occur semimonthly as the result of the Moon being in quadrature. **Figure E-6** compares the NOAA predicted tide with Loxahatchee model output at station BoyScoutDock. In the four months period, there are eight spring tides and eight neap tides in between. (The spring tide at the beginning and the end of the period make one complete spring tide and is counted as one.)

3.1.3 Comparison of Model Tide Output and NOAA Predicted Tide

Before the salinity model was calibrated and verified, the model was calibrated and verified to ensure that the hydrodynamic model can generated tides correctly. Since no continuous tidal record has been located for the model calibration and verification period, the model output was compared with NOAA Tide Table. **Figure E-6** presents both model output and NOAA predicted tide at station BoyScoutDock. This station is the most upstream (inland) station that is listed in the NOAA Tide Table. Model output was also verified against data of other NOAA sites at Middle and Lower Estuary and at the Jupiter Inlet.

3.2 The Influence of Freshwater Input on the Salinity Regime in the Estuary

3.2.1 Response Time

The estuarine salinity regime is the result of a dynamic process that involves mainly tides and freshwater inflow. Transition of estuarine salinity regime occurs constantly in response to the changes in tides and freshwater inflow. Even if the freshwater inflow is constant, there is a significant variation in salinity within each tidal cycle. On the other hand, daily average salinity does tend to reach a quasi-equilibrium state if freshwater inflow is steady. There is a time lag (response time) between the time of freshwater inflow change and the time when salinity adjustment is completed. If freshwater inflow is steady after the adjustment, daily salinity variation will stay within a fixed range with the same highs and lows everyday. At this point it is said that the salinity condition has reached a new equilibrium. Comparing a continuous concurrent flow and salinity record helps understand the response time of the system. **Figure E-7a** is flow and salinity record for a 10-day period in April 1999. Salinity at Station 65 (River Mile 8.6) went up by about 7 ppt after a 30-cfs freshwater input decrease at the Lainhart Dam.

Since the difference between the spring tide and the neap tide has a significant impact on salinity levels, the salinity changes due to freshwater input changes are often overshadowed by tide regime transition. To further investigate the salinity response time, a model simulation was designed. The mean tide range of 2.46' was applied to the entire simulation so that the impact of freshwater inflow rate can be detected clearly. **Figure E-7b** is the model output for three locations in the Northwest Fork. Although there are certain variations in response time in field data, they appear to be mostly completed within a 10-day time window. This is consistent with the model output in **Figure E-7b**. The speed of transition is proportional to the magnitude of the difference between the current condition and the anticipated equilibrium condition. Therefore a large portion of salinity adjustment takes place in the early stage of the transition. While it takes about 8 to 10 days to complete the salinity regime transition and reach a new equilibrium completely, 90% or more of the changes appear to be completed in 5 to 6 days.

3.2.2 Relationship between Freshwater Input and Salinity Regime in Northwest Fork

Modeling Approach

The estuary receives freshwater input from numerous sources; it is necessary to find a surrogate that could represent the freshwater input level. Due to the lack of data for groundwater and flow from other tributaries, the model calibration was based on the historic flow record at Lainhart Dam to estimate the total freshwater input to the system. While the model was not able to repeat all the fluctuations over the 6-month period, it did reproduce the general trend rather accurately. This seems to confirm that the flow rate at Lainhart dam can be used as a surrogate of overall freshwater input amount. This also shows the potential that the discharge at Lainhart Dam could be a management target. In the model simulations described below the total freshwater input was linked to the discharge at the Lainhart Dam with the flow ratios that were applied in model calibration and verification.

Another indicator was needed to describe the salinity condition at certain sites. Considering that the tidal range variation between spring and neap tides is another major factor that affects the salinity, a 28-day tidal cycle with two spring tides and two neap tides was chosen for all the flow scenario simulations. The model predicts salinity for each of the over 3000 nodes at 30 minutes intervals. To reduce the amount of information for analysis at this level, the model output was filtered to select high tide and low tide salinity only. Then the 56 high tide salinity and 56 low tide salinity were averaged to find the mean high tide salinity and the mean low tide salinity for the 28-day period. This data retrieval and processing was completed for 13 sites in the Northwest Fork, the middle and lower estuary, and at the inlet.

Freshwater Flow Scenarios

Two series of model simulations were conducted. Simulation #1 was developed using calculations of flow data for tributaries based on flow ratios applied in model calibration and verification. In contrast, Simulation #2 consists of a flow scenario with minimum amount of freshwater input from the three tributaries. Simulation #2 was considered the worst case scenario while Simulation #1 was developed to provide salinity conditions at various freshwater input levels that follow historic pattern. 10 cfs groundwater input was added to the Northwest Fork and its three major tributaries based on the model calibration results. Table 1 through Table 3 listed the flow scenarios of Simulations #1 and #2.

3.3 Results of Simulation #1

The output of the 11 model runs in each simulation scenario were analyzed to find the "average tide salinity" and the "average low tide salinity". The results of Simulation #1 are condensed into two color plates that are attached to this document **(Figures E-12 and E-13)**. The charts include the flow-salinity relationships at seven sites in the Northwest Fork. On the horizontal axis of these charts, the amount of freshwater input was represented by the flow rate at the Lainhart Dam. Given a flow rate on the horizontal axis and draw a vertical line from that point, the line will intersect the seven curves in the chart. Then the salinity of the seven intersecting points can be read from the vertical axis. These are the predicted salinity for the seven locations in the Northwest Fork Loxahatchee River with the given freshwater discharge.

The flow/salinity relationship for one of the sites, Site 8a at River Mile 8.1, are plotted in **Figures E-8 through E-11**.

A more detailed discussion on Simulation #1 results can be found in the conclusion section of this document.

4. Discussion

The model was able to follow the general trend of salinity changes that was observed in the system. This seems to confirm that the freshwater inflow rate at Lainhart Dam can be used as an surrogate indicator of total freshwater input to the estuary. On the other hand, the lack of flow data from several major tributaries limited the model to the calibration/verification at longer (weekly to monthly) time scales. When more data becomes available, the model can be further improved and verified at short (daily) time scales. This is important to model applications that require accurate simulation of transition process at small time steps.

Groundwater input is a major factor in the salinity balance of the system, especially under dry conditions. The groundwater input to the system is affected by groundwater table and river stage. The constant groundwater input assumption used in this study is just the first step in bringing groundwater into consideration. When the preliminary model results are applied to conditions where groundwater input could be less during an extended drought or more after a rainy season, the chart reading should be adjusted accordingly.

Precipitation and evaporation are not simulated in the current model. While this is acceptable for alternative comparisons, precipitation and evaporation should be included in the model at the next step to improve the model accuracy. The model is capable of simulating precipitation and evaporation.

The model results have been highly summarized in this document. The dynamic nature of the system response is not fully reflected in the charts that are presented. The original model output contains a huge amount of information that describes the dynamic process in the system.

When new information on freshwater inflow, groundwater input, continuous tide record, precipitation and evaporation becomes available, the model can be improved to provide more accurate results.

The modeling results described in this document is concentrated in the Northwest Fork. Since the model mesh covers the entire estuary it can be potentially applied to studies in other areas, including middle and lower estuary and the inlet, within the model mesh.

5. Conclusions

The Loxahatchee Estuary Salinity Model was developed using field data that had been acquired since the previous major salinity modeling effort for Loxahatchee Estuary. Compared to the USGS model developed in early 80s, the current model was able to cover the upstream portion of the Northwest Fork where the Loxahatchee River District has established long-term salinity records. The model output is consistent with the results of field measurements and indicates a clear correlation between salinity condition and freshwater inflow rate. The relationship described in this document, when combined with the results of biological studies, could provide a scientific basis for system management decision making.

Both field data analysis and the model output indicate a strong correlation between the amount of freshwater input and the estuarine salinity regime. The upstream portion of Northwest Fork is especially sensitive to changes in the freshwater input. Both the field data and model results indicate that a change of freshwater input as small as 10 cfs can cause detectable salinity changes in the area.

To facilitate the management decision making process, maps of 2-ppt salinity lines were prepared based on model output (**Figures E-14 and E-15**). **Figure E-14** shows the spatial positions of 2-ppt salinity lines with various freshwater inflow rates at high tide. **Figure E-15** shows the 2-ppt lines at low tide. The maps are summaries of a series of 9 model simulations with various freshwater inflow rates. Since the salt wedge is closely associated with 2-ppt salinity line, these two maps illustrate the relationship between salt wedge position and freshwater inflow rate. Salt wedge moves following tides. Therefore maps were developed at both high and low tides.

The difference between spring and neap tides is also a significant factor. To present the 2-ppt lines under an average tide condition, the results in **Figures E-14** and **E-15** were taken at a tide range of 2.48 ft at Jupiter Inlet. The mean tidal range there is 2.46 ft according to NOAA data. Therefore the results presented on the maps are under an "average tidal condition". The 2-ppt lines shown in these maps will be at about the middle point between the position of salt wedge at spring tides and that at the neap tides.

2-ppt salinity line locations can also be interpreted from charts in **Figures E-12 and E-13**. **Table E-4** is based on flow ~ salinity relationship presented in **Figure E-12**. The table listed the flow rate of freshwater input that is required to maintain salinity below 2-ppt at various locations in the Northwest Fork.

Table E-4. Simulation #1 Results: Freshwater inflow required to maintain high tide salinity below 2 ppt at seven locations along the Northwest Fork of the Loxahatchee River

River Mile	Station #	Freshwater discharge into Northwest Fork above Kitching Creek (cfs)*	Estimated discharge at Lainhart Dam(cfs)
6.5	#63	424	187
7.5	7B	291	128
7.7	#64	202	89
8.1	8A	168	74
8.6	#65	123	54
8.9	8st	95	42
9.4	#66	64	28

* = assume an additional 40 cfs from groundwater that is not included in this number.

Charts in **Figures E-12** and **E-13** were based on "average high tide salinity" or "average low tide salinity". Compared to the maps in Figures E-14 and E-15, the freshwater inflow rate subtracted from the charts in **Figures E-12** or **E-13** will tend to be conservative requiring a slightly higher freshwater inflow.

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Table E-1. Freshwater Input of Simulation #1 (without groundwater input)

RunSeries	LainhartDam	LOXTnpk	Trappers	CypressCrk	HobeGrv	KitchenCrk	NWFTotal	NF	S46
1	200	233	279	131	29	16	455	4	500
2	200	233	279	131	29	16	455	4	5
3	150	174	209	98	21	12	341	4	5
4	100	116	140	65	14	8	227	4	5
5	85	99	119	56	12	7	193	4	5
6	65	76	91	42	9	5	148	4	5
7	50	58	70	33	7	4	114	4	5
8	40	47	56	26	6	3	91	4	5
9	30	35	42	20	4	2	68	4	5
10	20	23	28	13	3	2	45	4	5
11	10	12	14	7	1	1	23	4	5
12	10	12	14	7	1	1	23	4	10
13	20	23	28	13	3	2	45	4	10

Table E-2. Freshwater Input of Simulation #1 (with groundwater input)

RunSeries	LainhartDam	LOXTnpk	Trappers	CypressCrk	HobeGrv	KitchenCrk	NWFTotal	NF	S46
1	200	233	289	141	39	26	495	4	500
2	200	233	289	141	39	26	495	4	5
3	150	174	219	108	31	22	381	4	5
4	100	116	150	75	24	18	267	4	5
5	85	99	129	66	22	17	233	4	5
6	65	76	101	52	19	15	188	4	5
7	50	58	80	43	17	14	154	4	5
8	40	47	66	36	16	13	131	4	5
9	30	35	52	30	14	12	108	4	5
10	20	23	38	23	13	12	85	4	5
11	10	12	24	17	11	11	63	4	5
12	10	12	14	7	1	1	23	4	10
13	20	23	28	13	3	2	45	4	10

Table E-3. Freshwater Input of Simulation #2 (Unit: cfs)

RunSeries	LainhartDam	LOXTnpk	CypressCrk	HobeGrv	KitchenCrk	NWFTotal	NF	S46
1	200	279	7	2	1	289	4	500
2	200	279	7	2	1	289	4	5
3	150	209	7	2	1	219	4	5
4	100	140	7	2	1	150	4	5
5	85	119	7	2	1	129	4	5
6	65	91	7	2	1	101	4	5
7	50	70	7	2	1	80	4	5
8	40	56	7	2	1	66	4	5
9	30	42	7	2	1	52	4	5
10	20	28	7	2	1	38	4	5
11	10	14	7	2	1	24	4	5
12	10	14	7	2	1	24	4	10
13	20	28	7	2	1	38	4	10

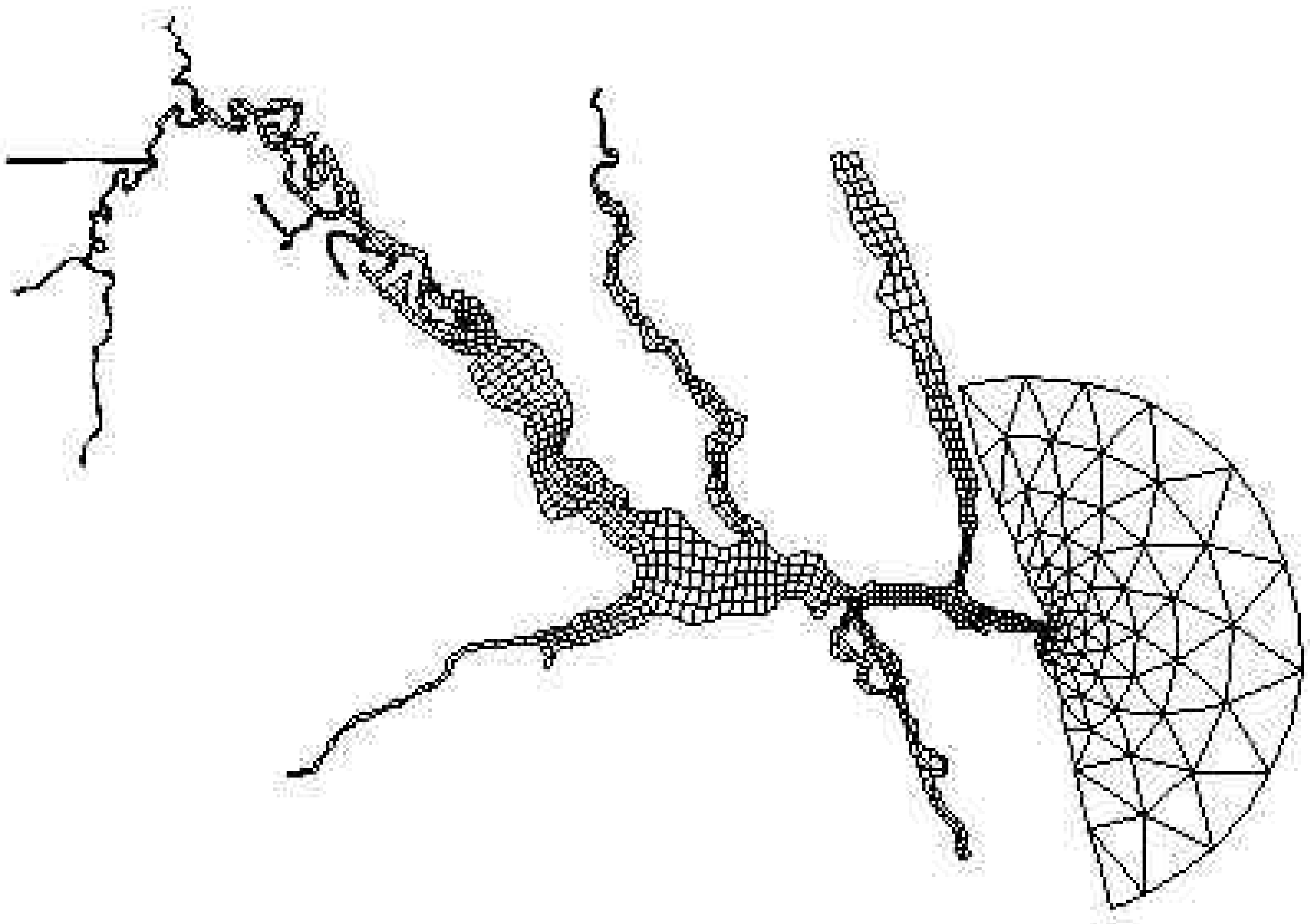


Figure E-1. Loxahatchee Estuary Model Finite Element Mesh

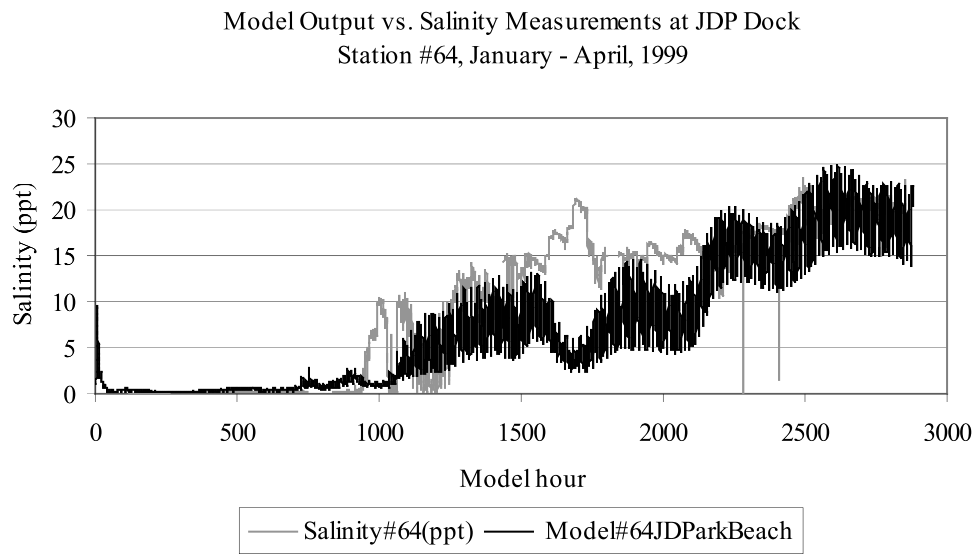


Figure E-2. Comparison of model output and field record at WQ Station 64

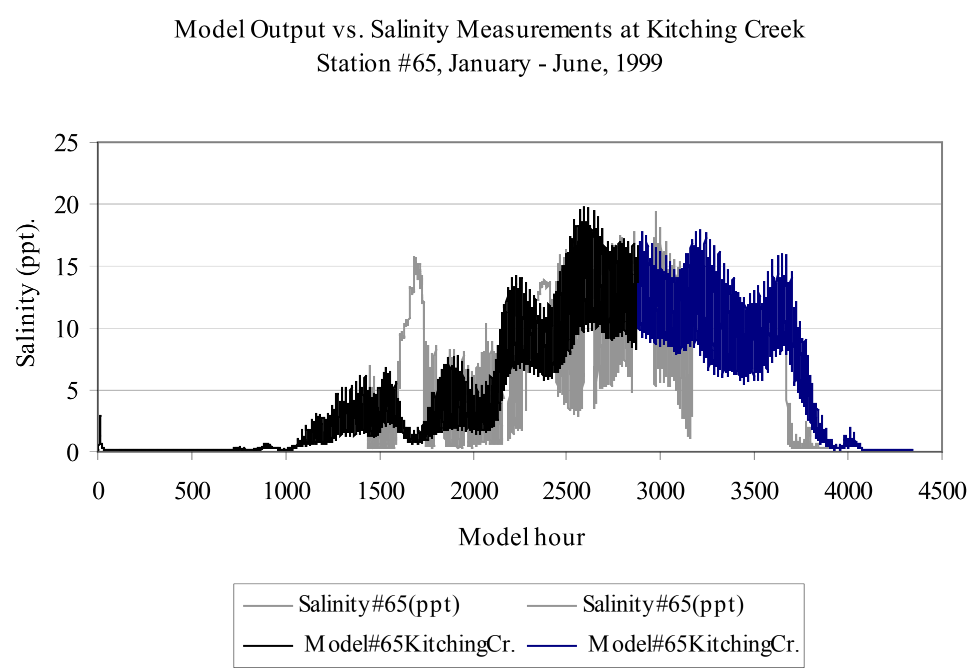


Figure E-3. Comparison of model output and field record at WQ Station 65

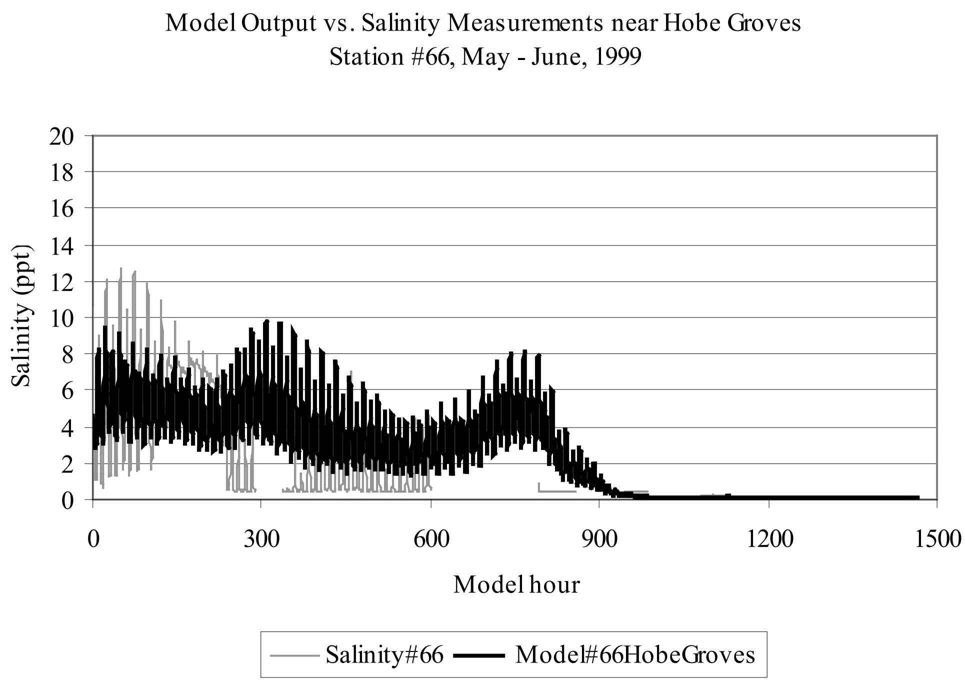


Figure E-4. Comparison of model output and field record at Station 66

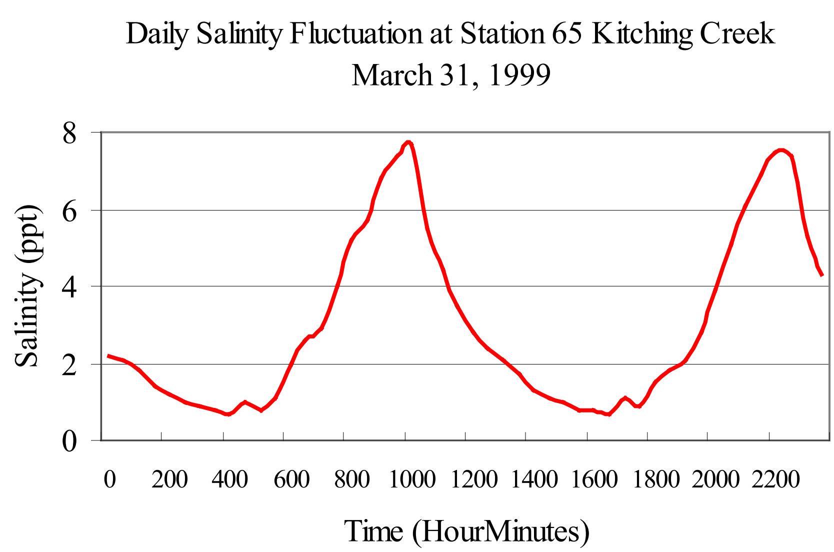


Figure E-5. Semidiurnal salinity fluctuation at Station 65

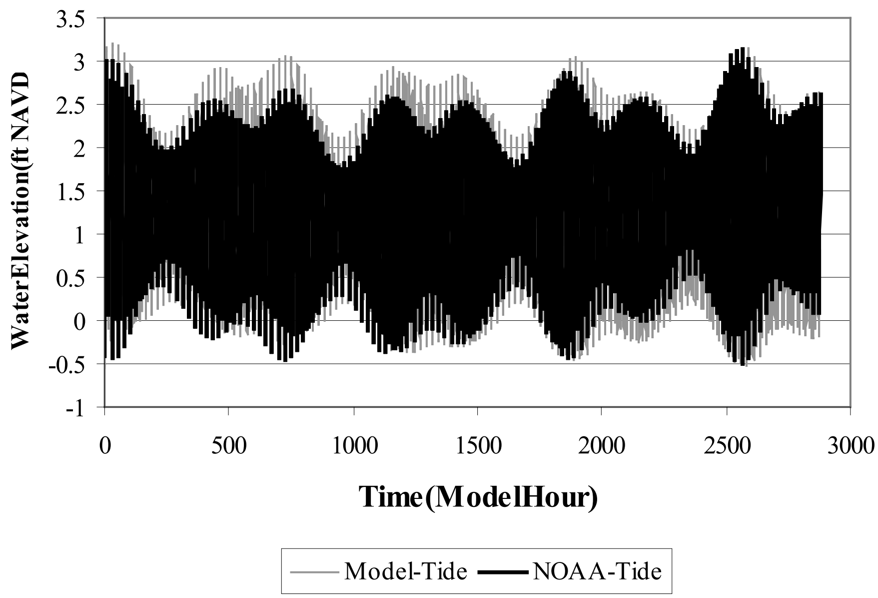
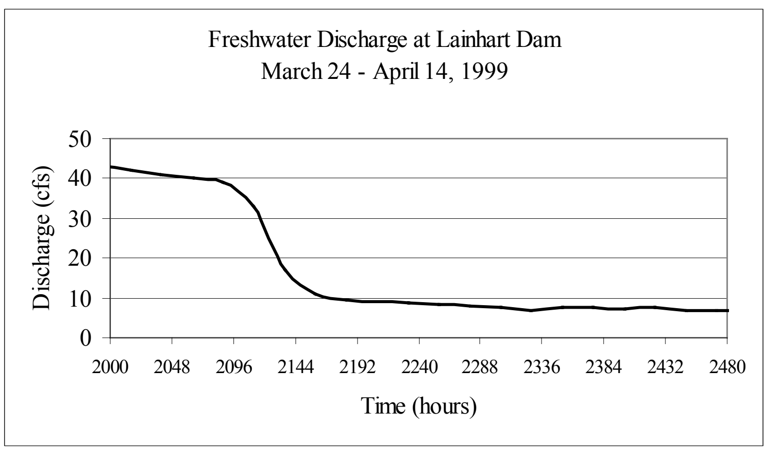


Figure E-6. Tides at Boy Scout Dock, January 1 - April 30, 1999



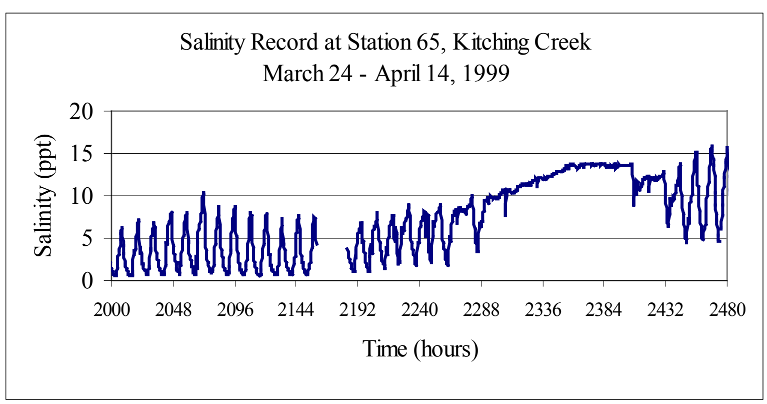


Figure E-7a. Transition of salinity regime in response to freshwater input change

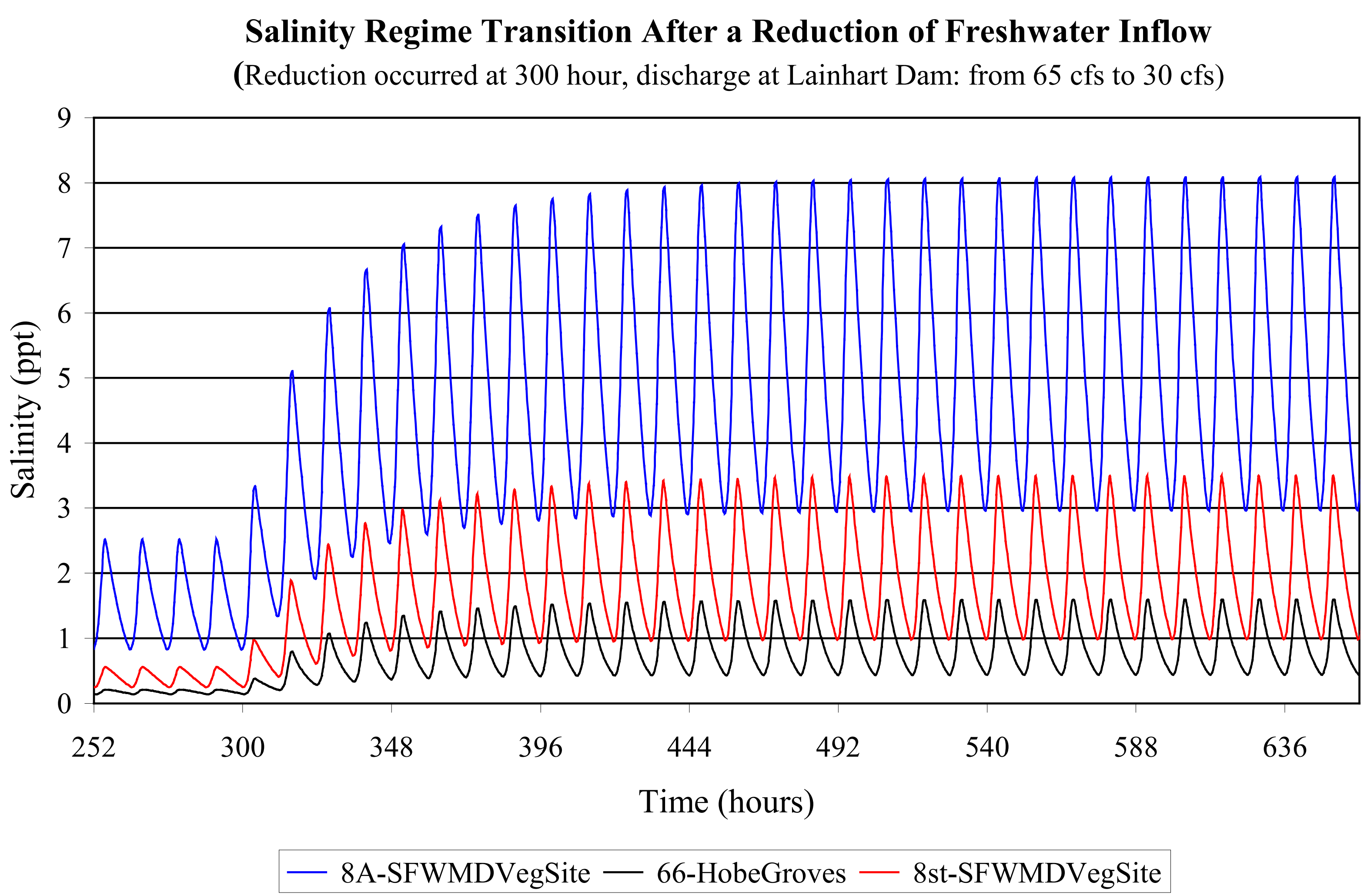


Figure 7b. System Response Time

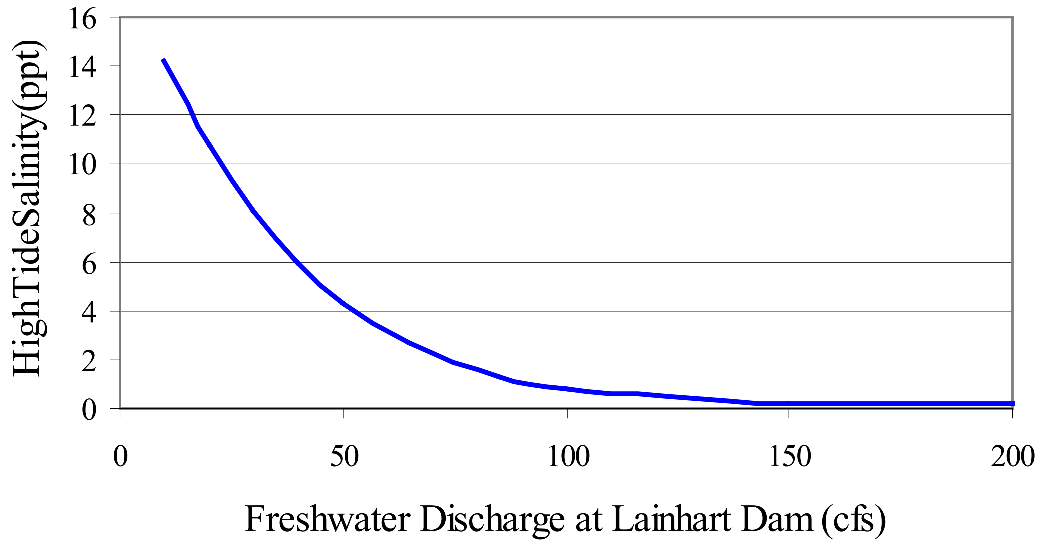


Figure E-8. High Tide Salinity at Station 8a Kitching Creek, Simulation #1

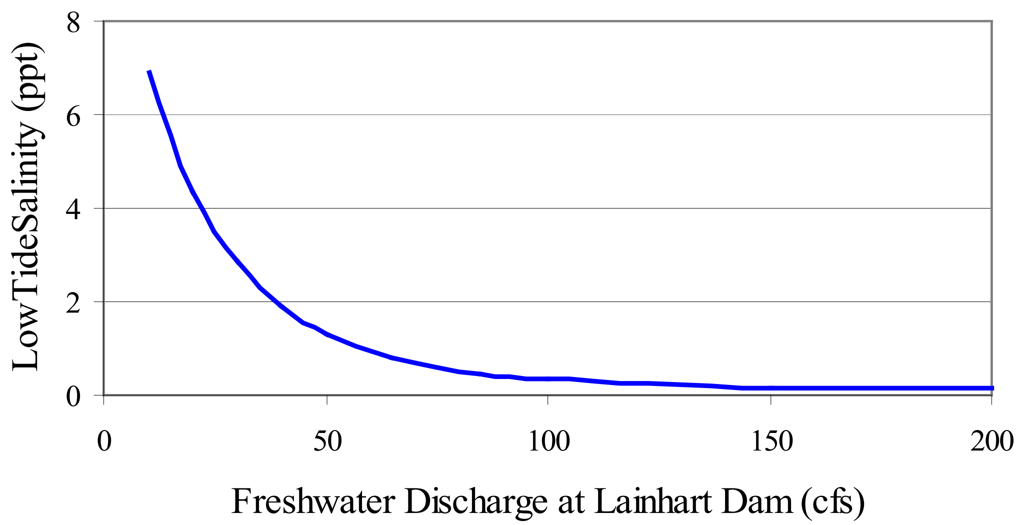


Figure E-9. Low Tide Salinity at Station 8a Kitching Creek, Run #1

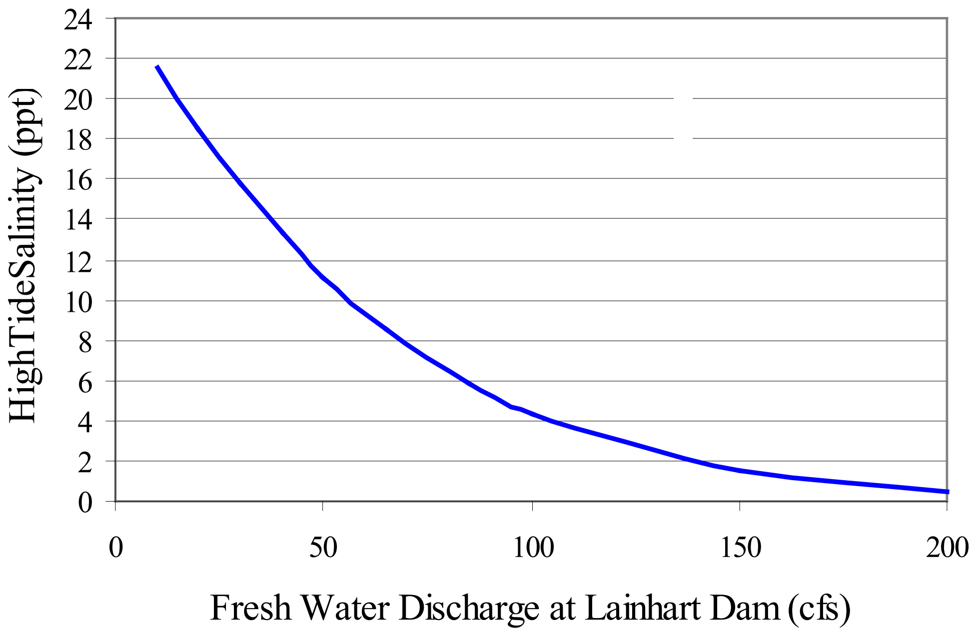


Figure E-10. High Tide Salinity at Station 8a Kitching Creek, Simulation #2

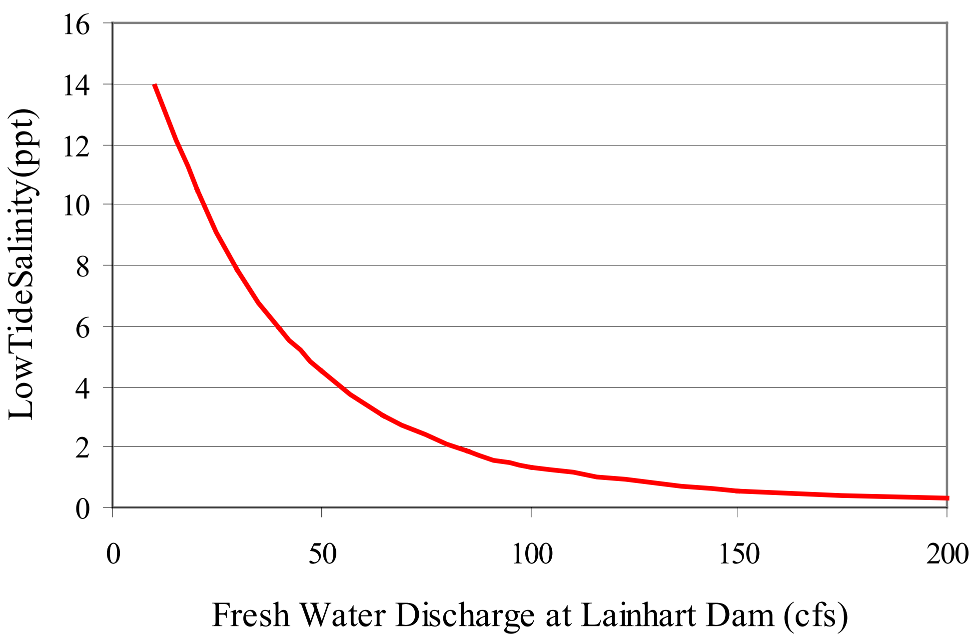


Figure E-11 . Low Tide Salinity at Station 8a Kitching Creek, Simulation #2

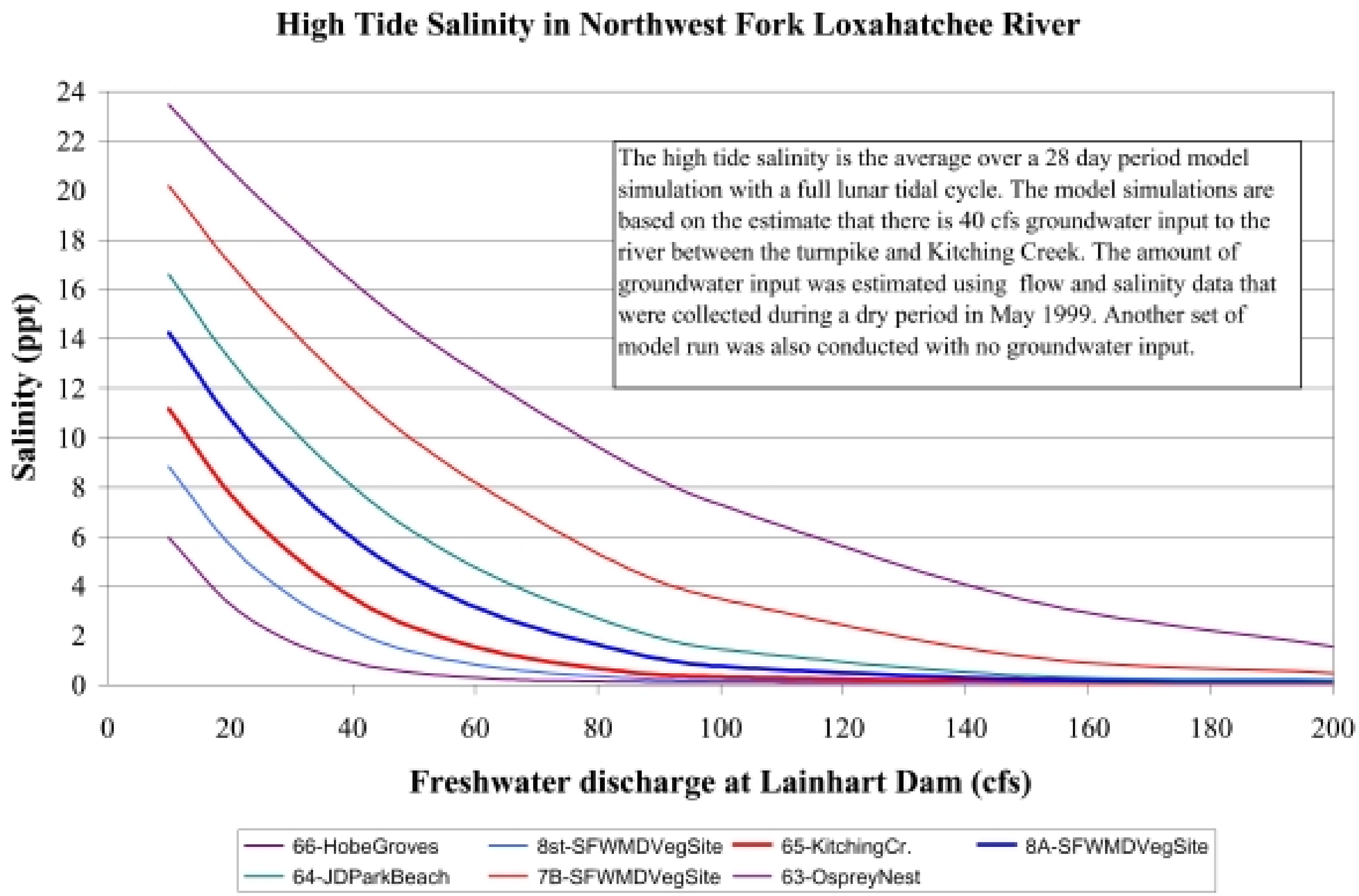


Figure E-12. The relationship between high tide salinity and the amount of freshwater inflow

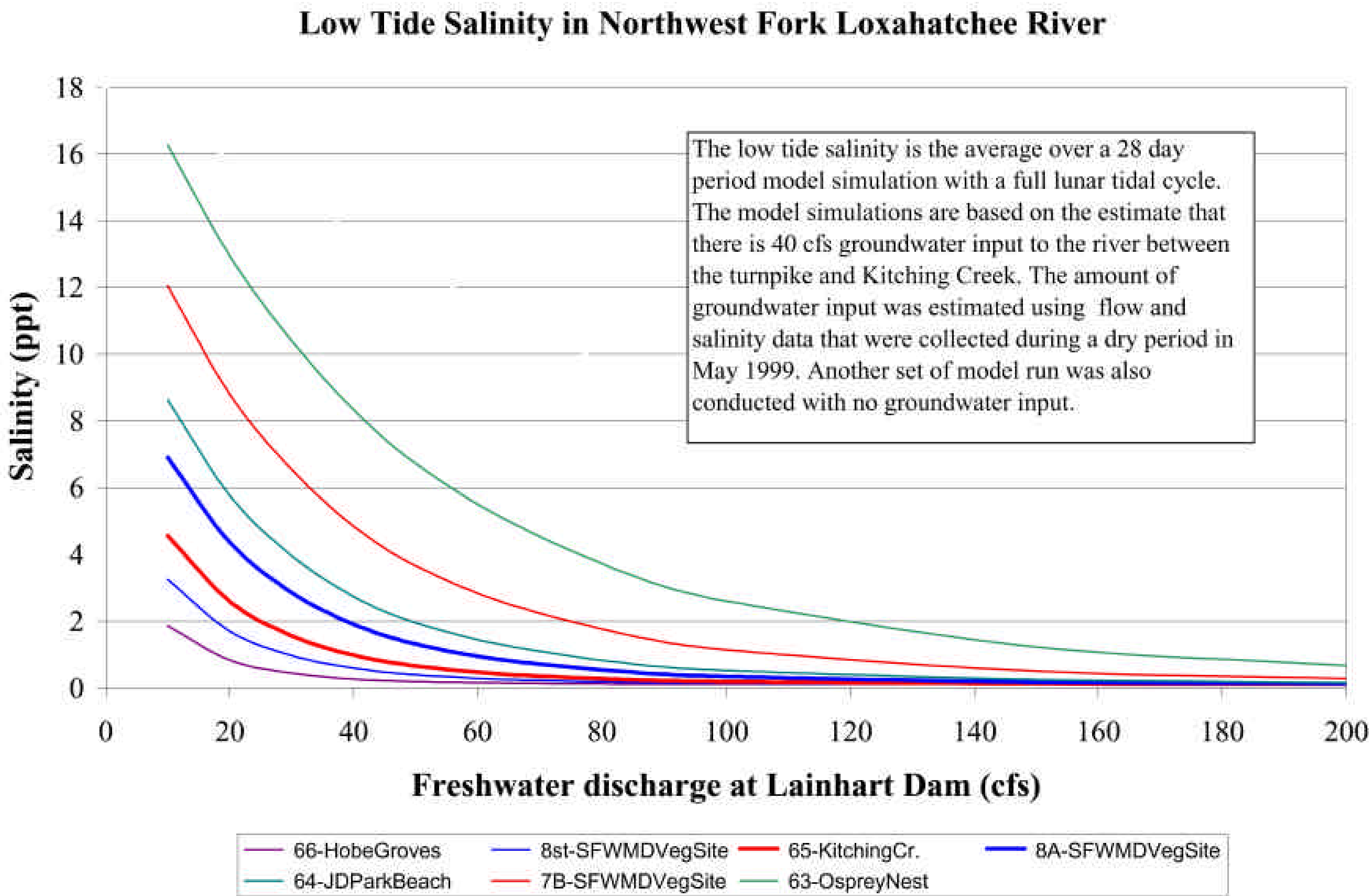


Figure E-13. The relationship between low tide salinity and the amount of freshwater inflow

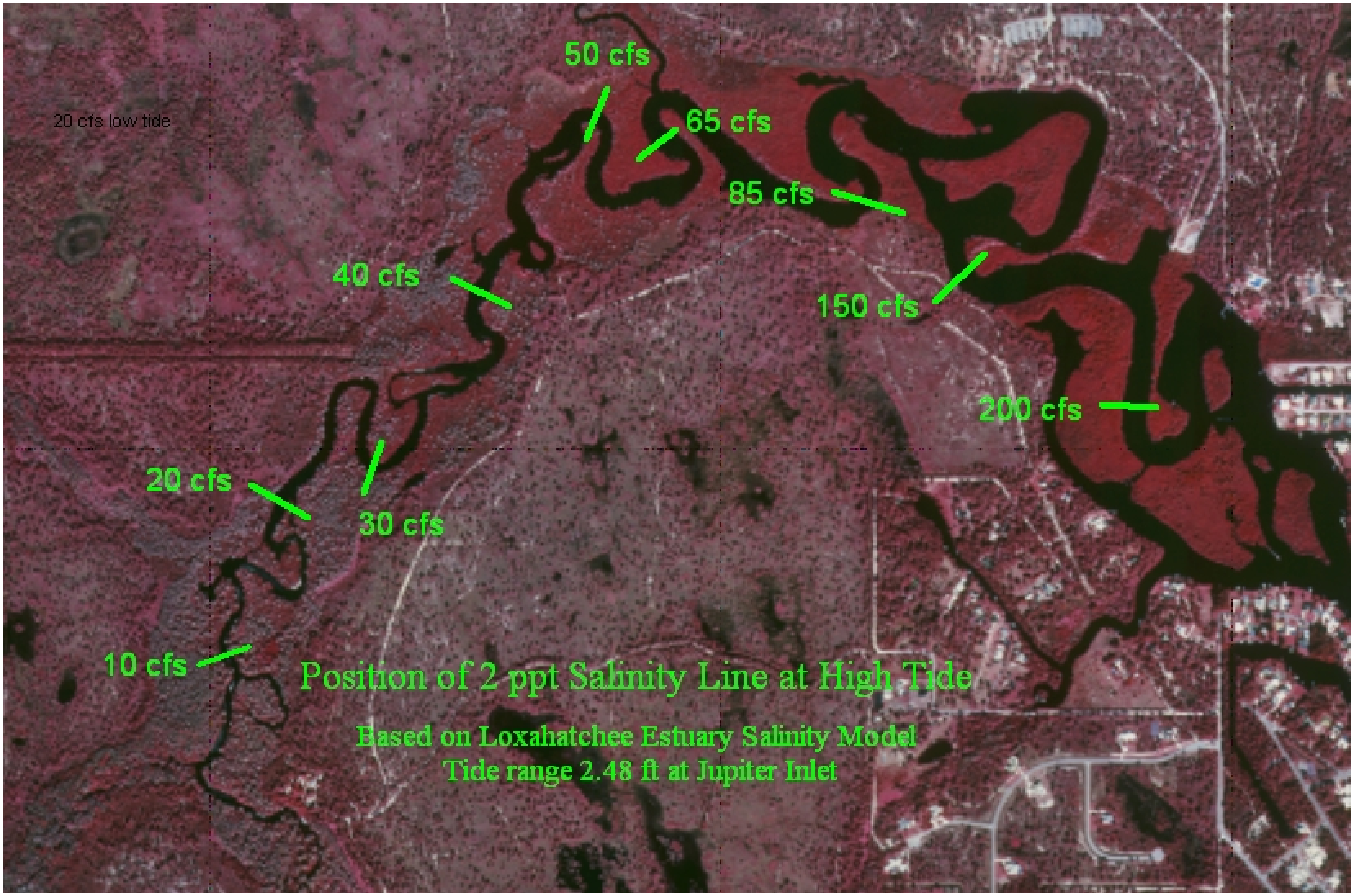


Figure E-14. Location of 2 ppt salinity-line position at high tide as a function of discharge from the Lainhart Dam (Simulation #1)

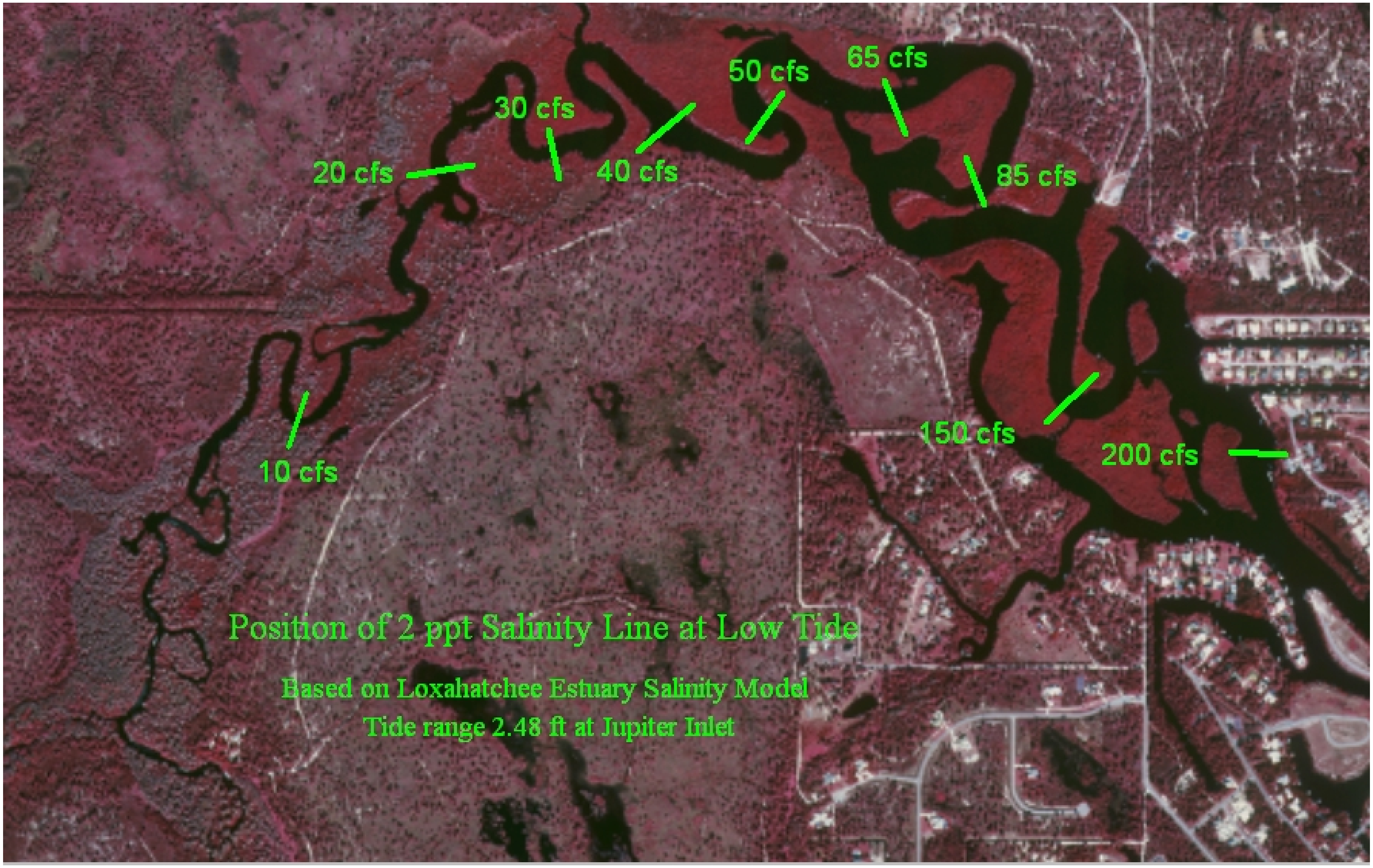


Figure E-15. Location of the 2 ppt salinity-line position at low tide as a function of discharge from the Lainhart Dam (Simulation #1)